Evaluating CERES TOA Flux using ARISE aircraft observations

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NASA Langley Research Center

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Arctic Radiation-IceBridge Sea ice Experiment (ARISE)

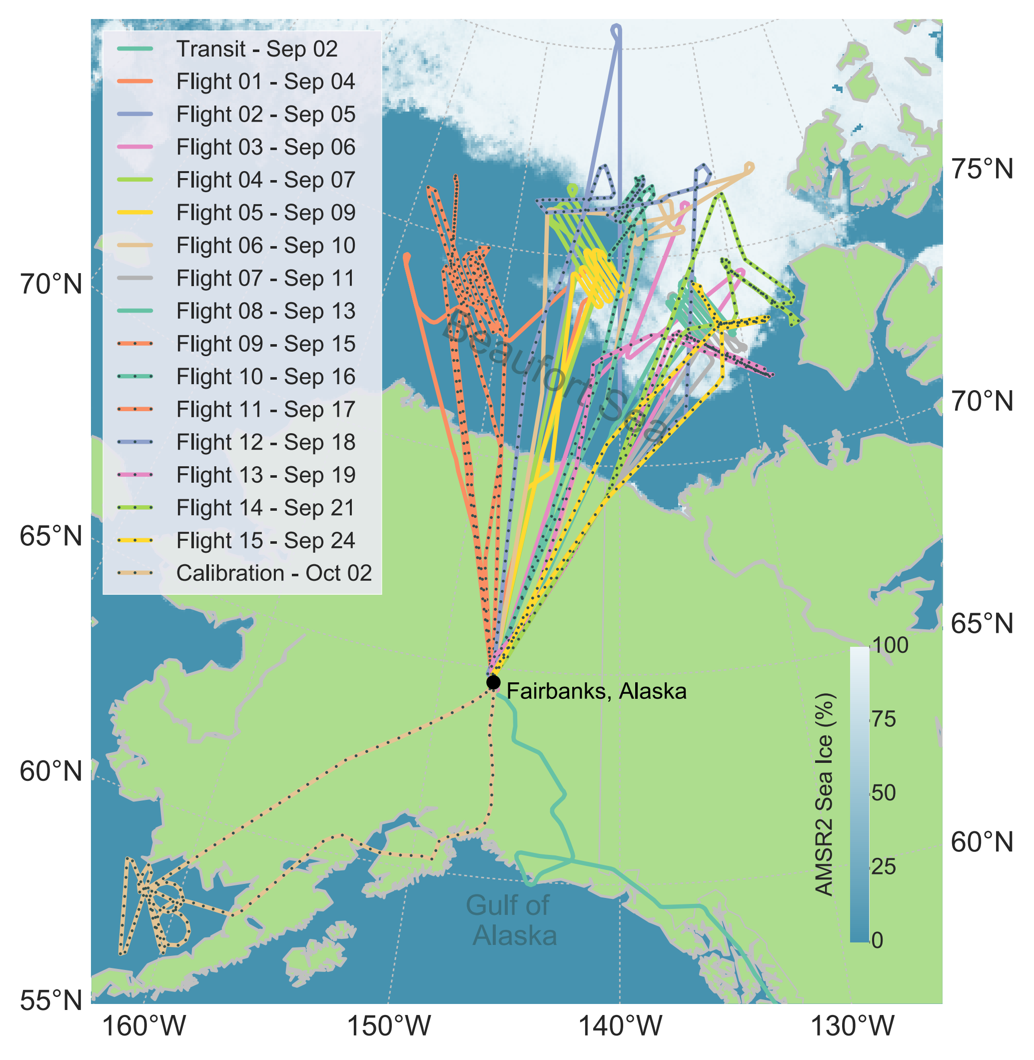
Based in Fairbanks, Alaska during September 2014

From the NASA C-130:

- Measure spectral and broadband radiative flux profiles
- Quantify surface characteristics, cloud properties, and other atmospheric state parameters under a variety of Arctic atmospheric and surface conditions
- Coincide with satellite overpasses as often as possible

Naval Research Laboratory Broadband Radiometers (BBR):

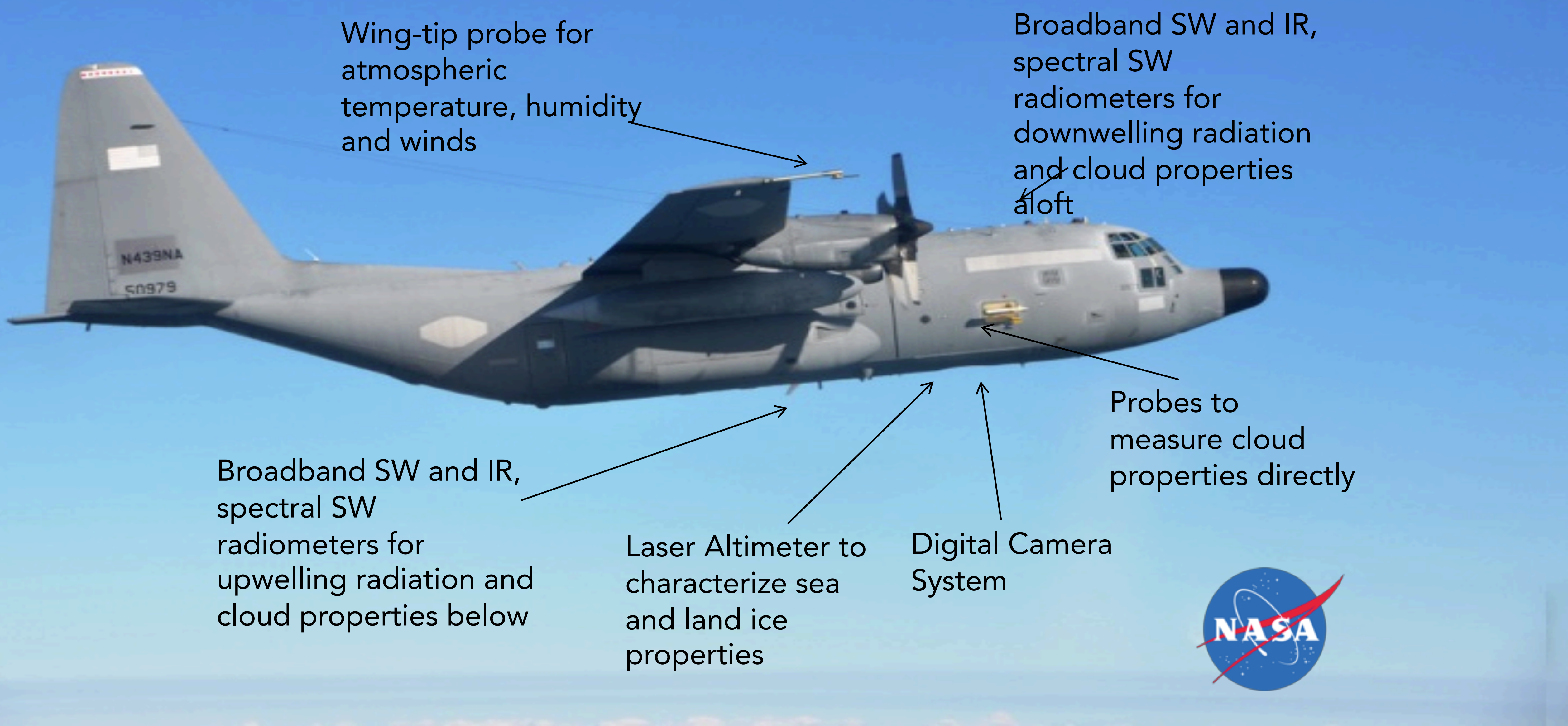
- SW up and down – modified Kipp and Zonen CM-22 pyranometers
- LW up and down – modified Kipp and Zonen CG-4 pyrgeometers
- estimated uncertainty ~ 3-5%



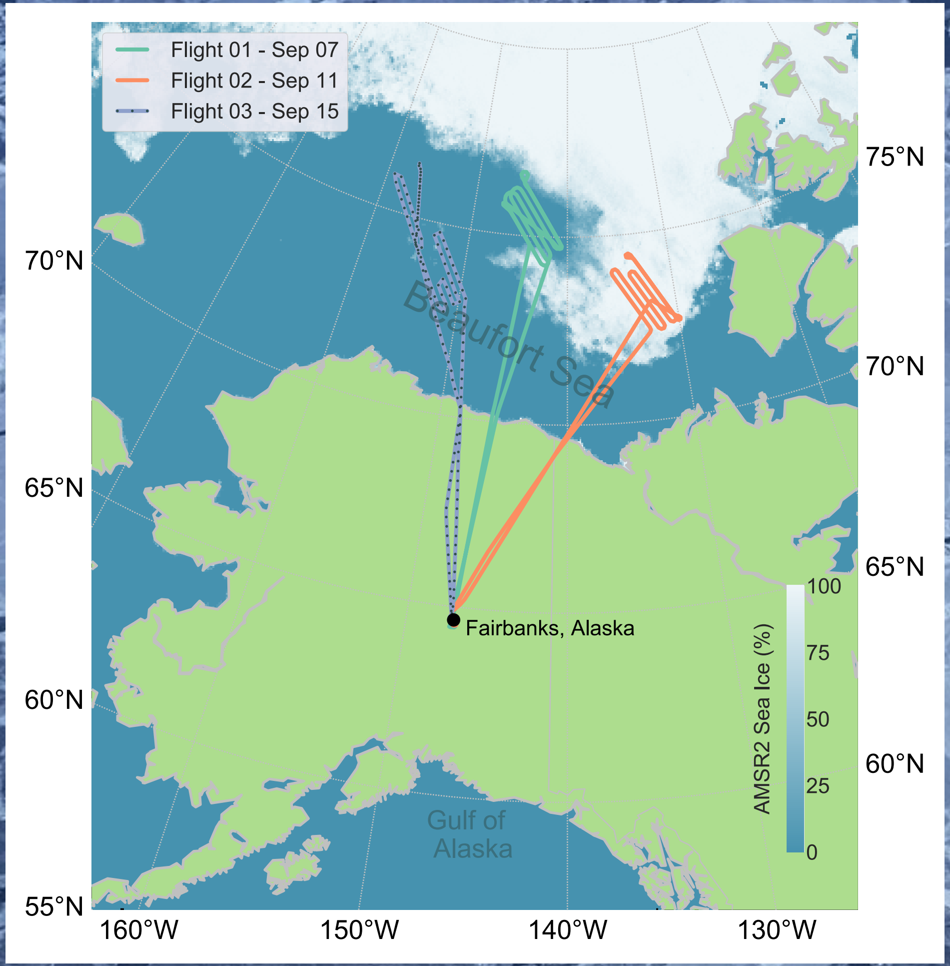
NASA C-130 PAYLOAD

Instruments	Measurement	Characteristics	Products
Broadband Radiometers (BBR) **A. Bucholtz, NRL**	SW and LW fluxes (↑, ↓) SW total, direct & diffuse (↓)	SW: modified K&Z CM-22 (0.2-3.6 µm) LW: modified K&Z CG-4 (4.5-45 µm) TDDR: Delta-Devices SPN-1 (0.4-2.7 µm)	Net SW, LW Irradiance, direct/diffuse SW partitioning, absorption, heating rates Surface albedo, cloud albedo
Spectral Solar Flux Radiometer (SSFR) **S. Schmidt, U. of Colo.**	Spectral SW fluxes (↑, ↓)	370-2170 nm, Resolution: 8-12 nm Leveling platform	Spectral fluxes, albedo Cloud properties
Spectral Sun-photometer 4STAR **J. Redemann, NASA ARC**	Spectral radiances (↓) Modes: direct beam, sky scanning, zenith	380-1700 nm	aerosols, gases, cloud properties above aircraft
Heitronics KT-19 **D. Van Gilst, NSERC/UND** **A. Bucholtz, NRL**	IR window radiance (↑, ↓)	9.6-11.5 µm	Skin temperature, sky and cloud temperature
Land, Vegetation, and Ice Sensor (LVIS) **B. Blair, M. Hofton, GSFC**	Geo-located waveform vector	1064 nm Scanning: 20 minute footprint, 2 km swath from 10 km Full waveform recorded	Surface elevation, Sea-ice freeboard, Melt-pond distribution Cloud top height

NASA C-130: An airborne radiometer (thermometer) with in-situ probes and a laser altimeter to characterize the surface, atmosphere and radiative effects of sea-ice and clouds



ARISE TOA gridbox experiments:



Three flight days focus on CERES TOA gridbox experiments:

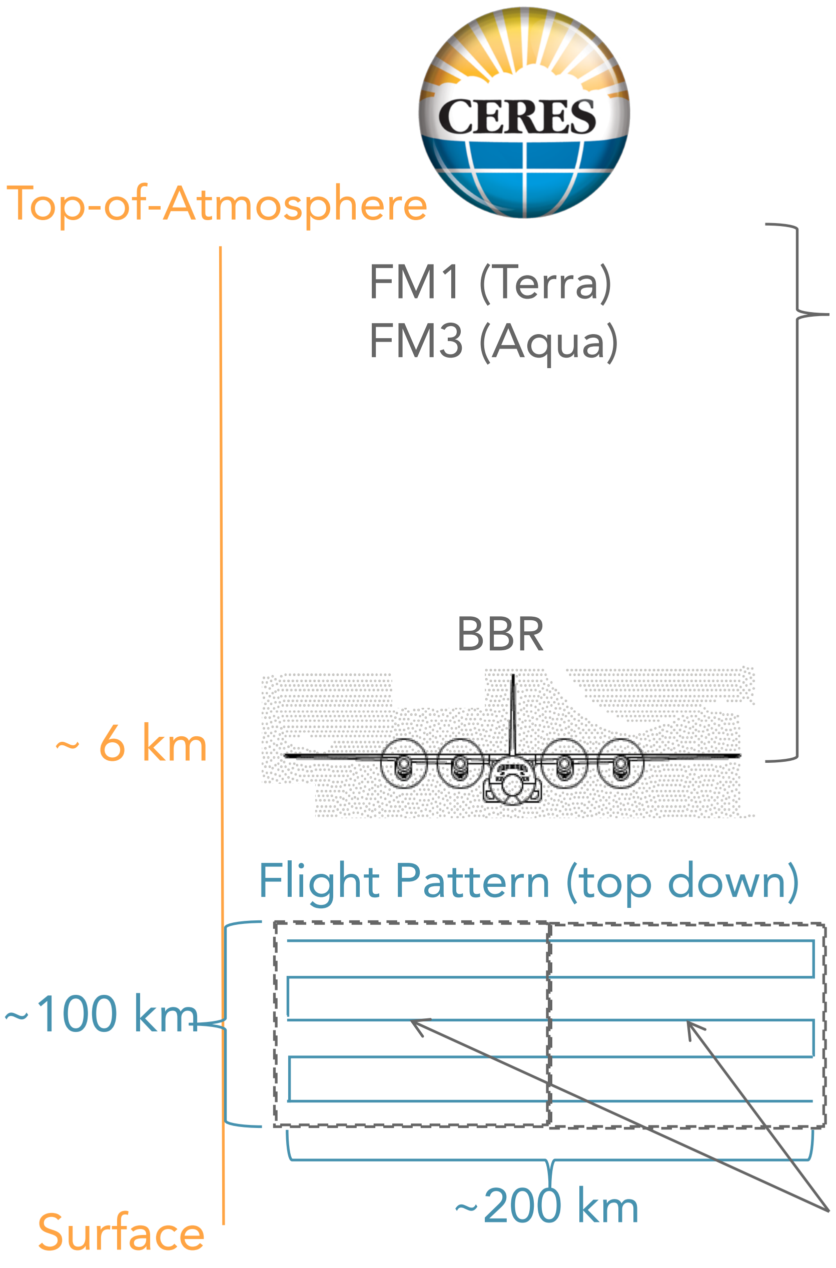
September 7, 2014: Marginal ice zone (two boxes)

September 11, 2014: High sea ice concentration (two boxes)

September 15, 2014: open ocean (one box)

A key ARISE objective was to evaluate CERES TOA and Surface data products.

CERES-Aircraft Comparison Methodology:



Need to account for:

LW - absorption

SW - scattering/absorption

Langley Fu-Liou Radiative transfer model:

- Atmospheric state information from GEOS 5.4.1
- Cloud property information from MODIS (CERES cloud group)
- Surface information from the AMSR2 ASI 3.5km sea ice concentration dataset (Uni. Hamburg)

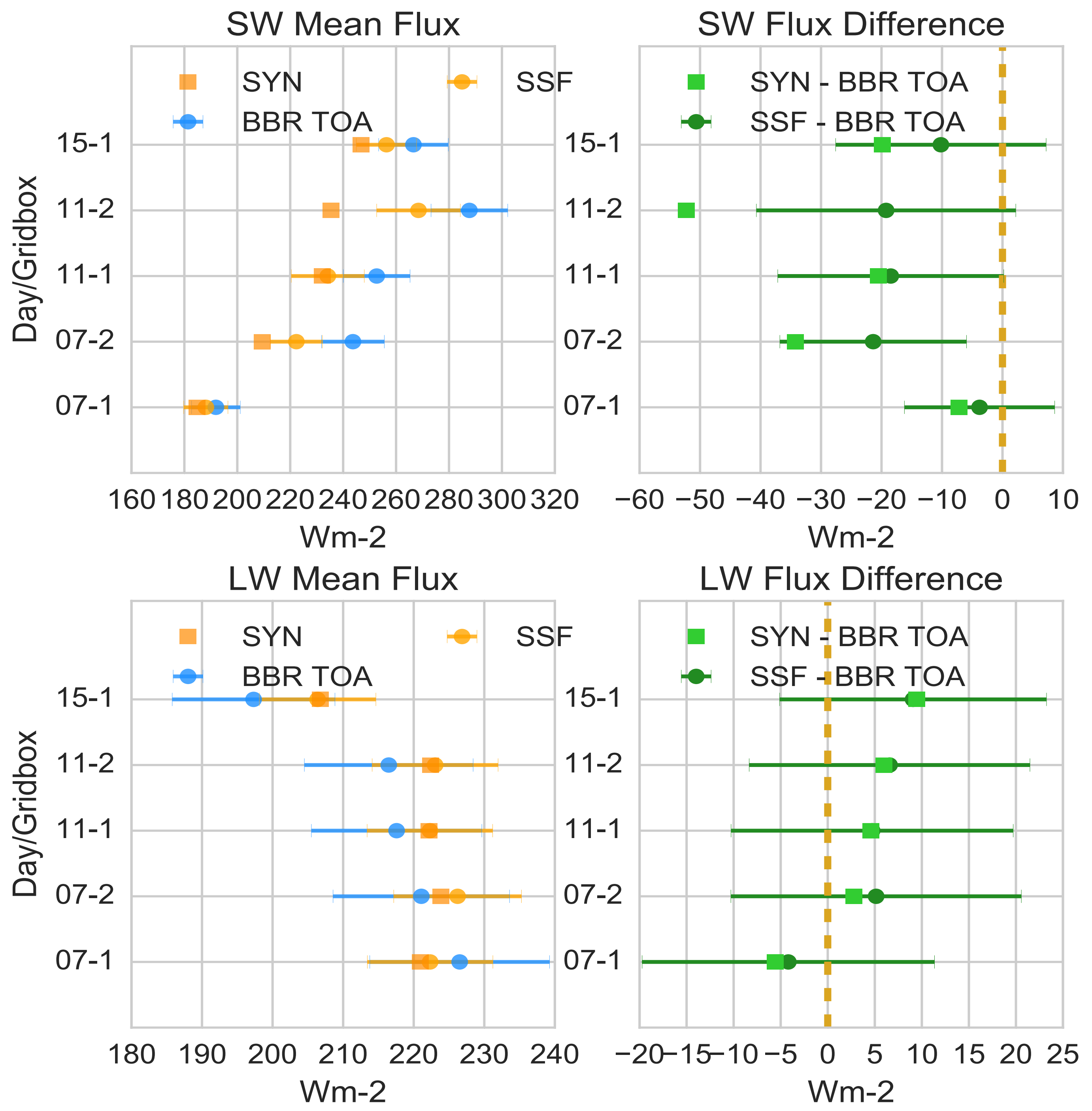
To convert BBR from 6 km to TOA:

$$\text{BBR TOA} = (F(TOA)_{\text{model}}/F(6km)_{\text{model}}) \times \text{BBR}$$

Compare mean BBR TOA and mean CERES fluxes for each grid box

ARISE TOA gridbox experiments :

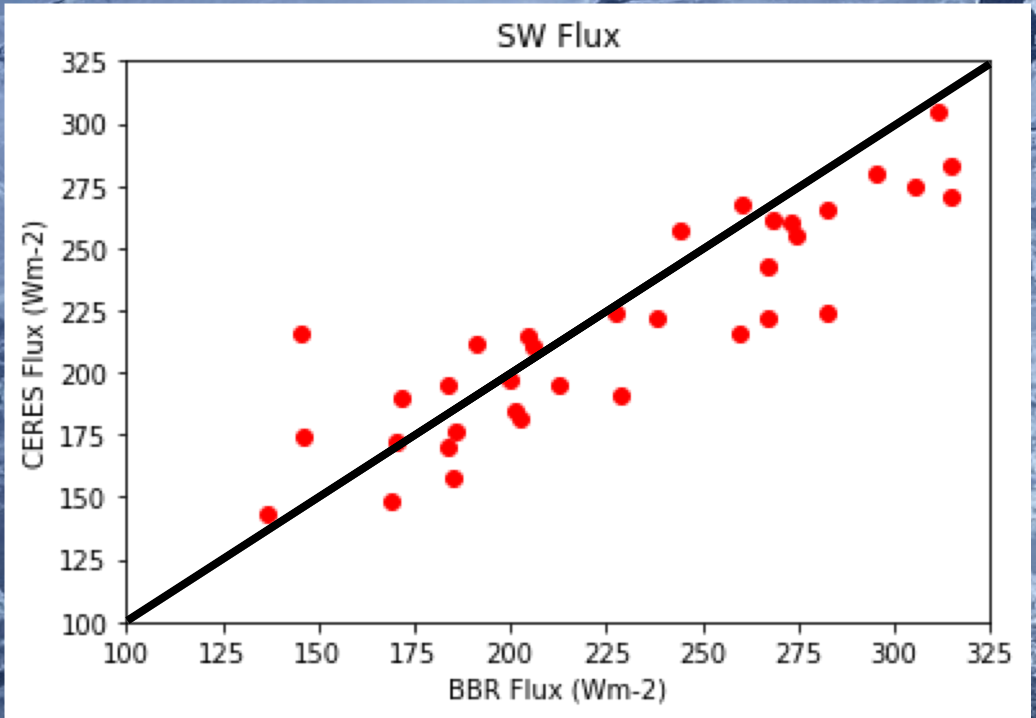
- Overcast ocean
- Partly cloudy sea ice
- Overcast sea ice
- Overcast MIZ
- Overcast MIZ

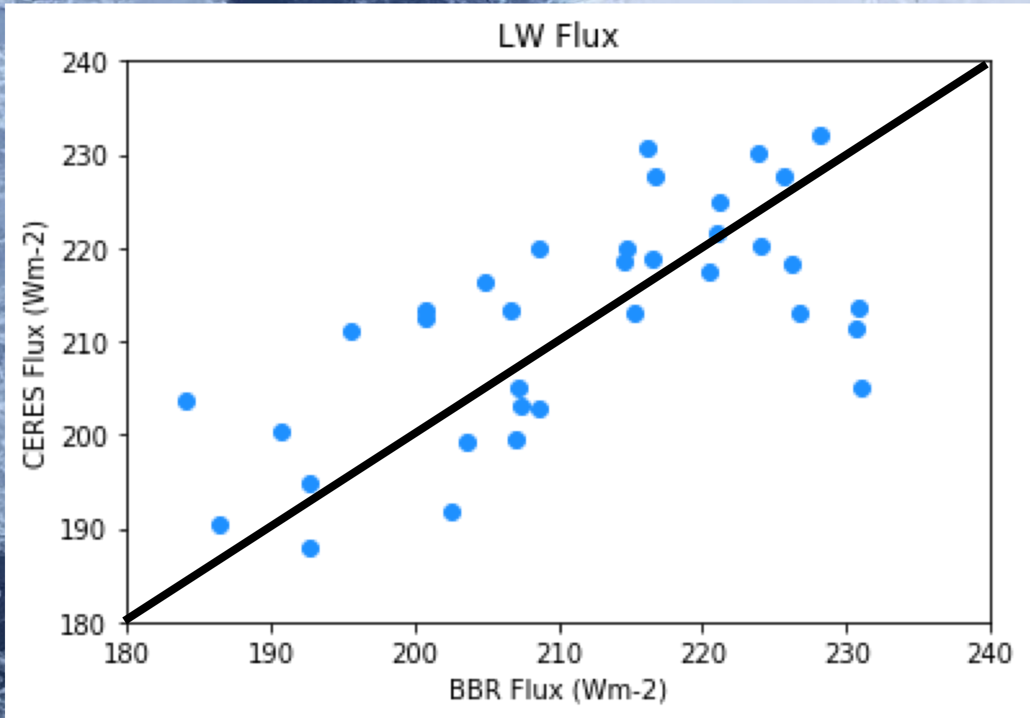


- LW shows good agreement for all grid-boxes (< +/- 2 Wm^{-2})
- SW shows agreement within uncertainty for 4/5 grid-boxes
- Cause of the negative biases?
  - Calibration
  - ADMs
  - Sampling

Instantaneous comparisons: 36 matched FOVs

- An alternative to the gridbox experiments is to compare only the instantaneous matches between aircraft and CERES FOVs
- Time match: within 15 minutes
- Despite the small number of samples, the overall results matches the gridbox experiments.





SW BBR and CERES mean difference: -10.54 Wm^{-2} (-4.9%)

LW BBR and CERES mean difference: 0.39 Wm^{-2} (0.2%)

September 7th: GB 07-1

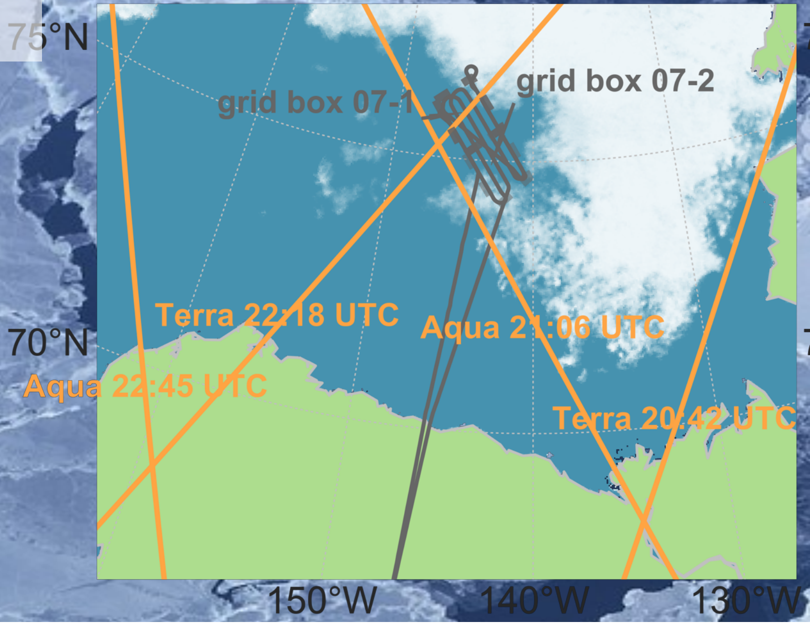
GB07-1:
Marginal Ice Zone, overcast and medium, thick low clouds

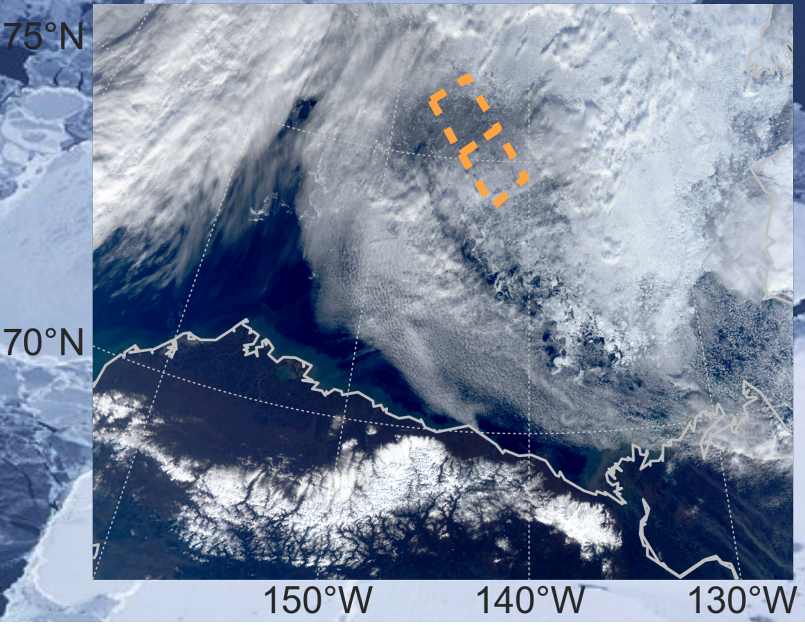
- **Cloud fraction:** 100%
- **COD:** 6.4
- **CTP:** 858 hPa
- **Sea ice:** 8.5%

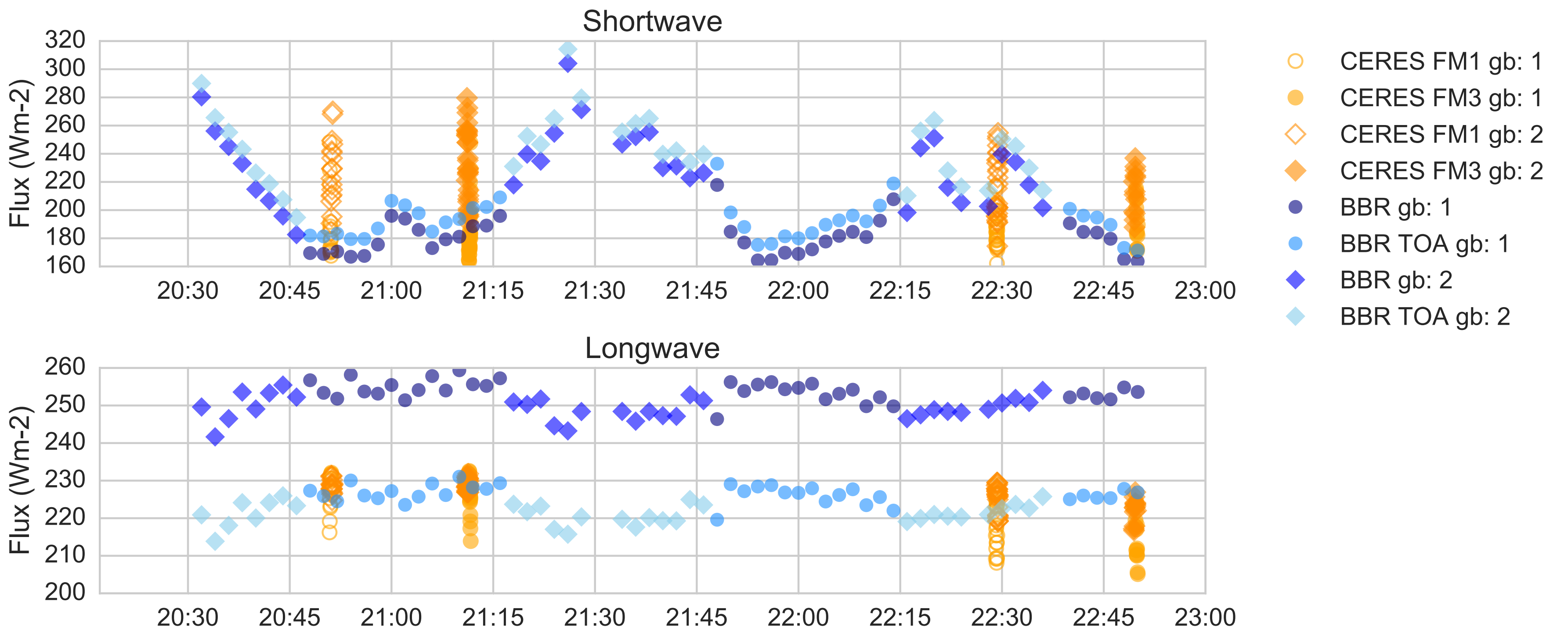
CERES SW Flux: 189.2 Wm^{-2}
CERES LW Flux: 223.0 Wm^{-2}
BBR SW Flux: 192.2 Wm^{-2}
BBR LW Flux: 228.5 Wm^{-2}

CERES SW:
FM1: 187.9 Wm^{-2} (48)
FM2: 199.2 Wm^{-2} (216)
FM3: 190.4 Wm^{-2} (47)

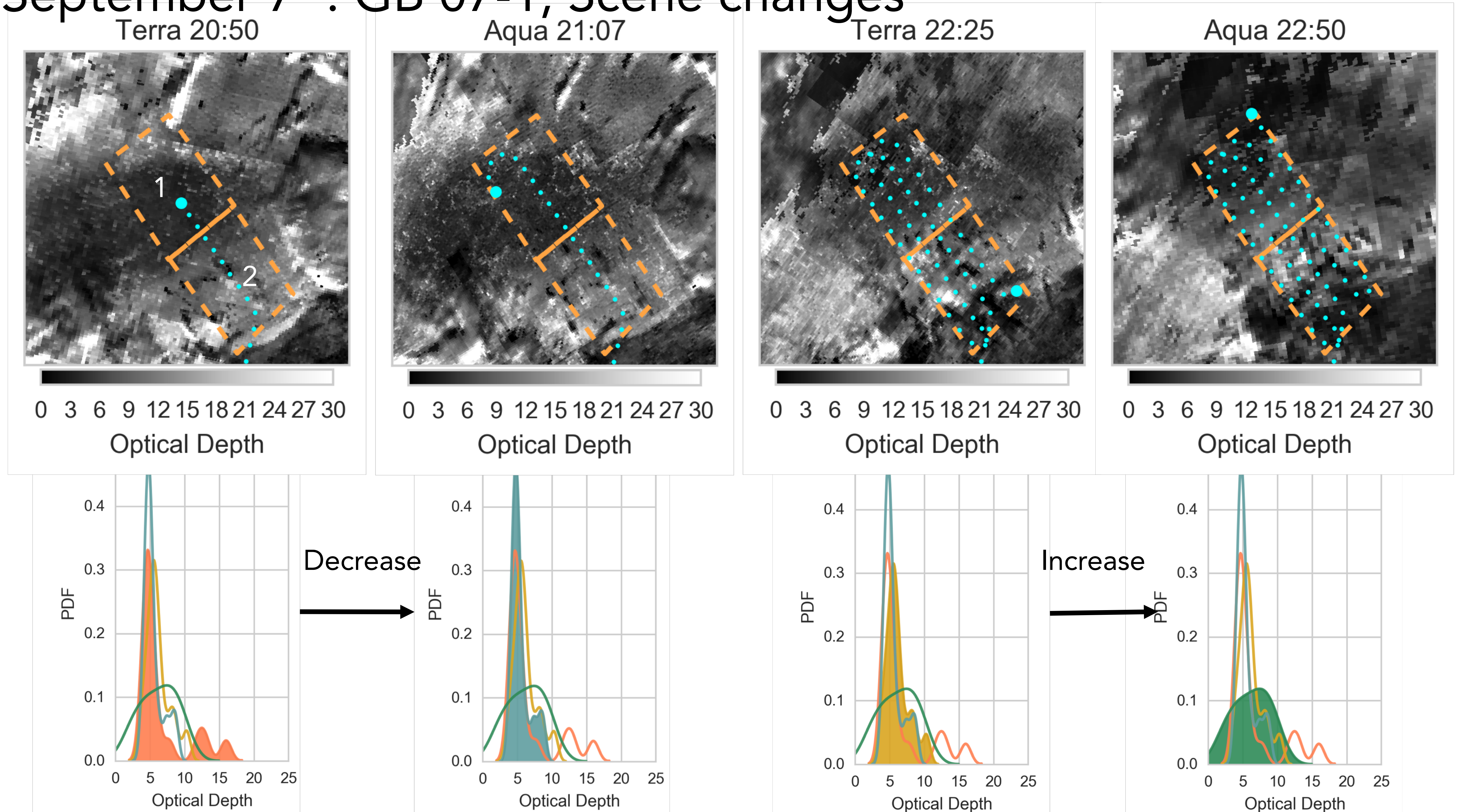
CERES LW:
FM1: 223.0 Wm^{-2} (48)
FM2: 222.9 Wm^{-2} (216)
FM3: 222.9 Wm^{-2} (47)







September 7th: GB 07-1, Scene changes

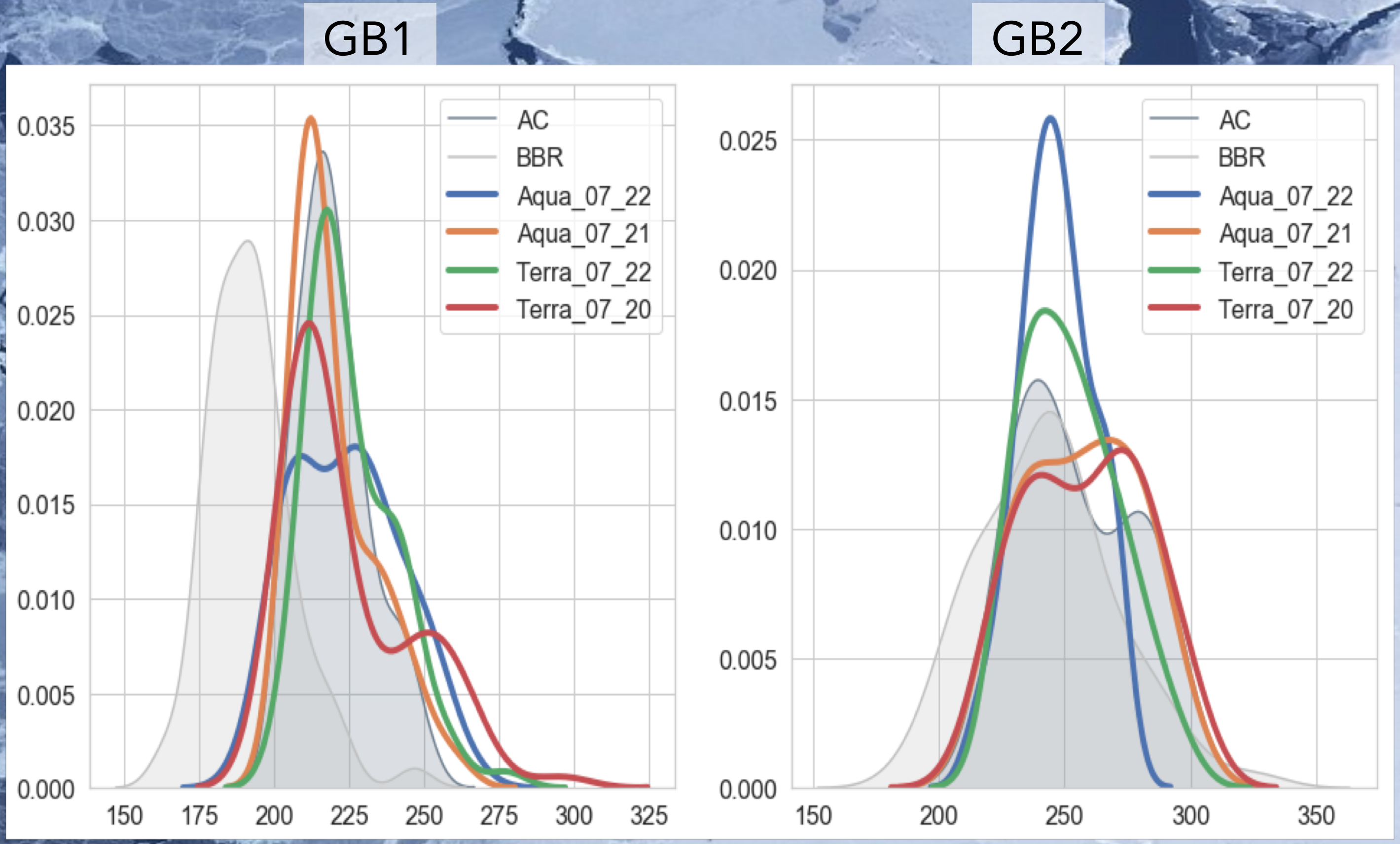


Sampling Differences between Aircraft and CERES: SW Flux

GB0701:
SW Flux:
Aircraft Sampling (closest matching): 220.1 Wm^{-2}
Terra_20 overpass: 224.7 Wm^{-2}
Aqua_21 overpass: 220.1 Wm^{-2}
Terra_22 overpass: 225.8 Wm^{-2}
Aqua_22 overpass: 224.1 Wm^{-2}
Mean of overpasses: 223.7 Wm^{-2}
Aircraft sampling bias: -3.6 Wm^{-2}

GB0702:
SW Flux:
Aircraft Sampling (closest matching): 255.1 Wm^{-2}
Terra_20 overpass: 258.4 Wm^{-2}
Aqua_21 overpass: 257.0 Wm^{-2}
Terra_22 overpass: 252.3 Wm^{-2}
Aqua_22 overpass: 247.0 Wm^{-2}
Mean of overpasses: 253.7 Wm^{-2}
Aircraft sampling bias: 1.4 Wm^{-2}

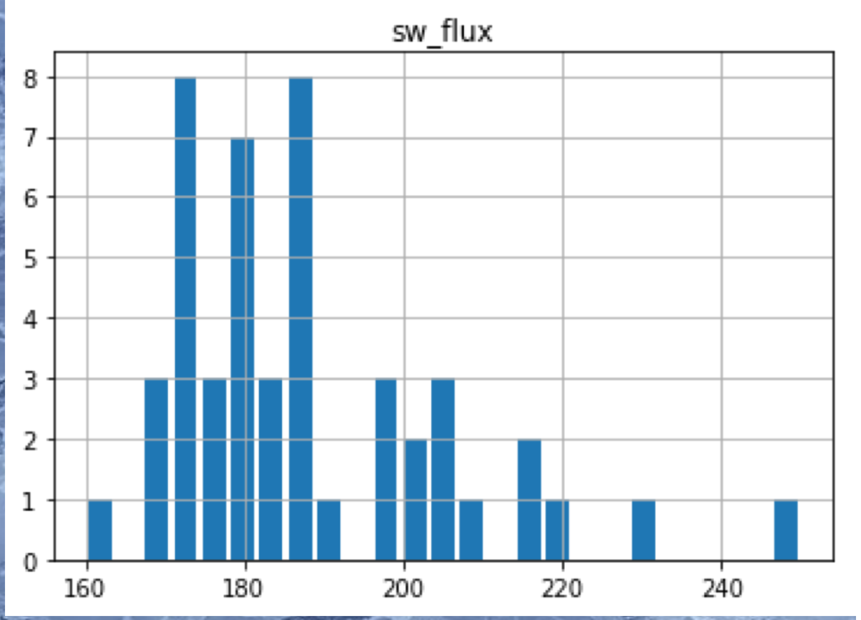
Simulated using MODIS radiances and NB-to-BB, then imposing the aircraft sampling.

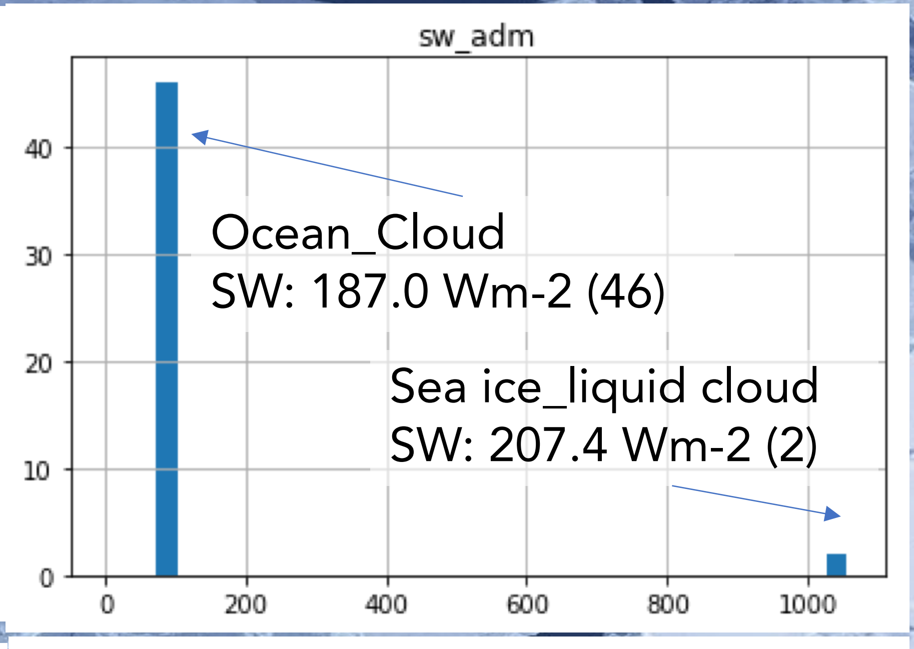


Aircraft sampling resulted in a 3.6 Wm^{-2} lower Aircraft flux than if the entire gridbox had been sampled and in GB0702 a 1.4 Wm^{-2} higher flux.

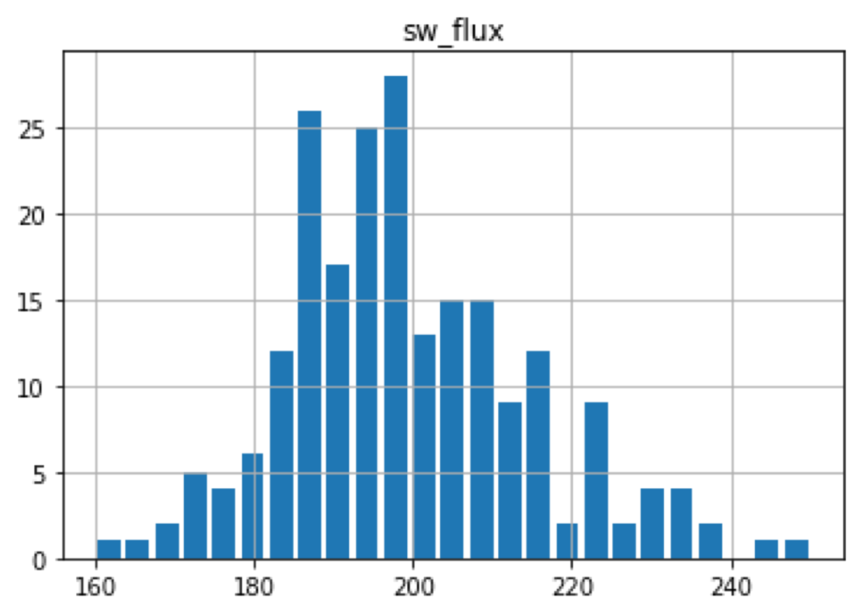
September 7th: GB 07-1, FM1 vs. FM2 comparison

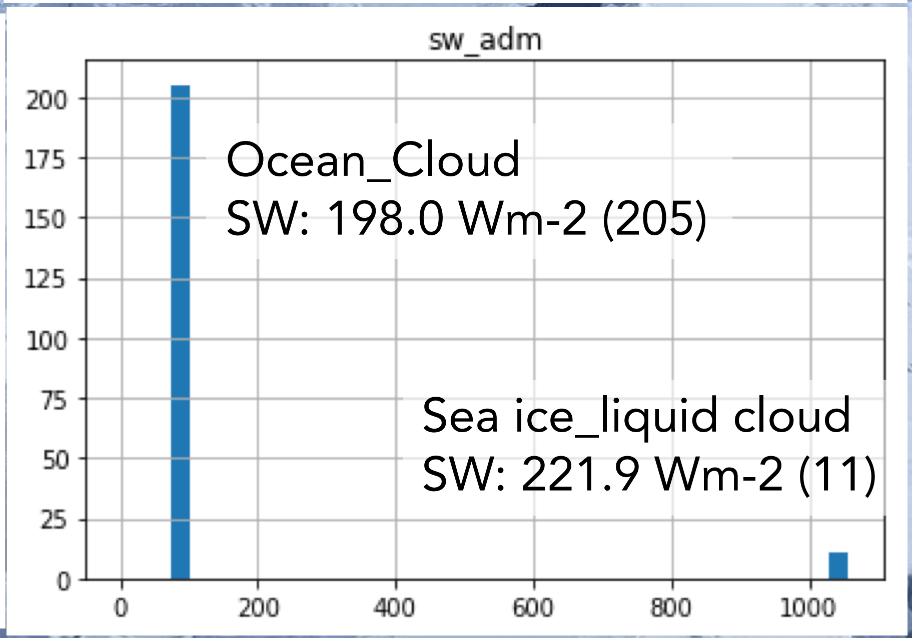
FM 1





FM 2





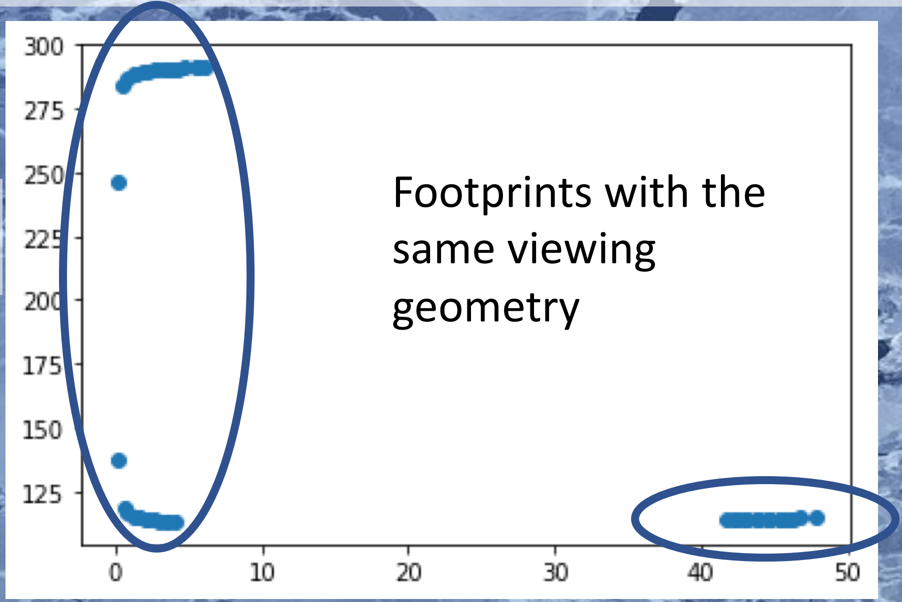
- FM1 only observed 2 sea ice footprints.
- FM2 observed a higher SW flux than FM1 over cloudy sky ocean footprints.

GB07-1: Marginal Ice Zone, overcast and medium thick low clouds, FM1 vs FM2 comparison (Viewing geometry)

FM1 CERES SW Flux: 187.9 Wm-2 (48)
FM2 CERES SW Flux: 199.2 Wm-2 (216)
FM1 CERES LW Flux: 223.0 Wm-2
FM2 CERES LW Flux: 222.9 Wm-2

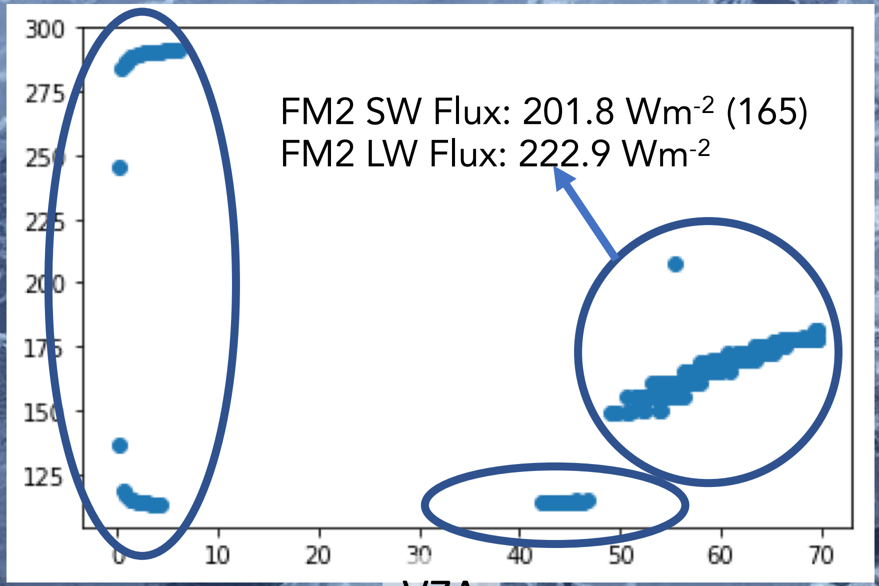
FM 1

RAZ



FM 2

RAZ



VZA

For VZA ,< 10 (all but 3 FOVs cloudy-sky ocean (FM1: 2 and FM2: 1)

- FM1 CERES SW Flux: 187.8 Wm^{-2} (31)
- FM2 CERES SW Flux: 189.6 Wm^{-2} (32)
- FM1 CERES LW Flux: 220.7 Wm^{-2}
- FM2 CERES LW Flux: 220.7 Wm^{-2}

For 40< VZA 50 (all but 1 FOV (FM 2) cloudy-sky ocean)

- FM1 CERES SW Flux: 188.1 Wm^{-2} (17)
- FM2 CERES SW Flux: 192.7 Wm^{-2} (19)
- FM1 CERES LW Flux: 227.1 Wm^{-2}
- FM2 CERES LW Flux: 226.1 Wm^{-2}

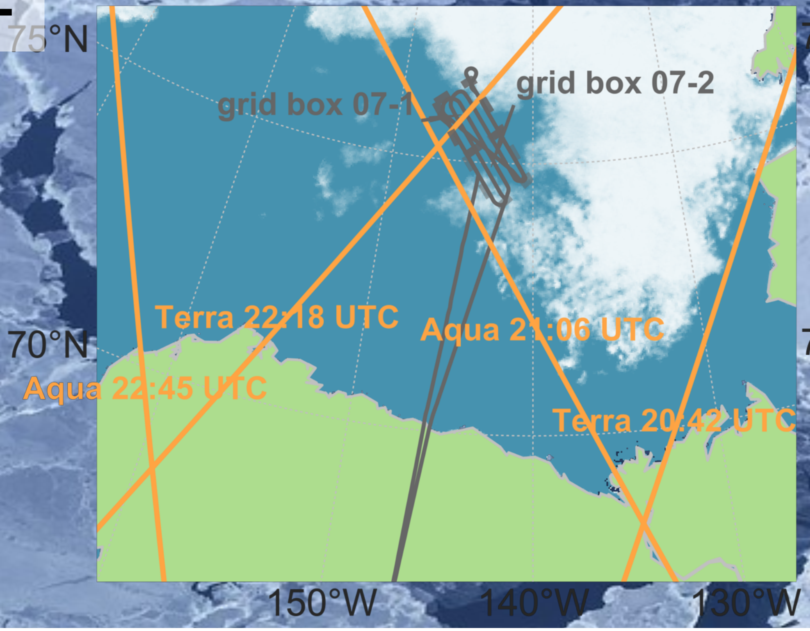
This 4 Wm^{-2} difference is due to the 1 sea ice FOV for FM2

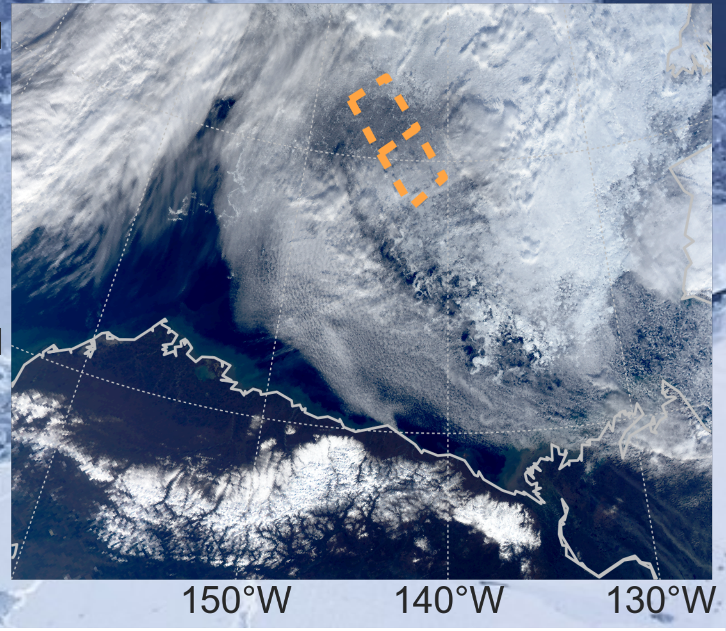
September 7th: GB 07-2

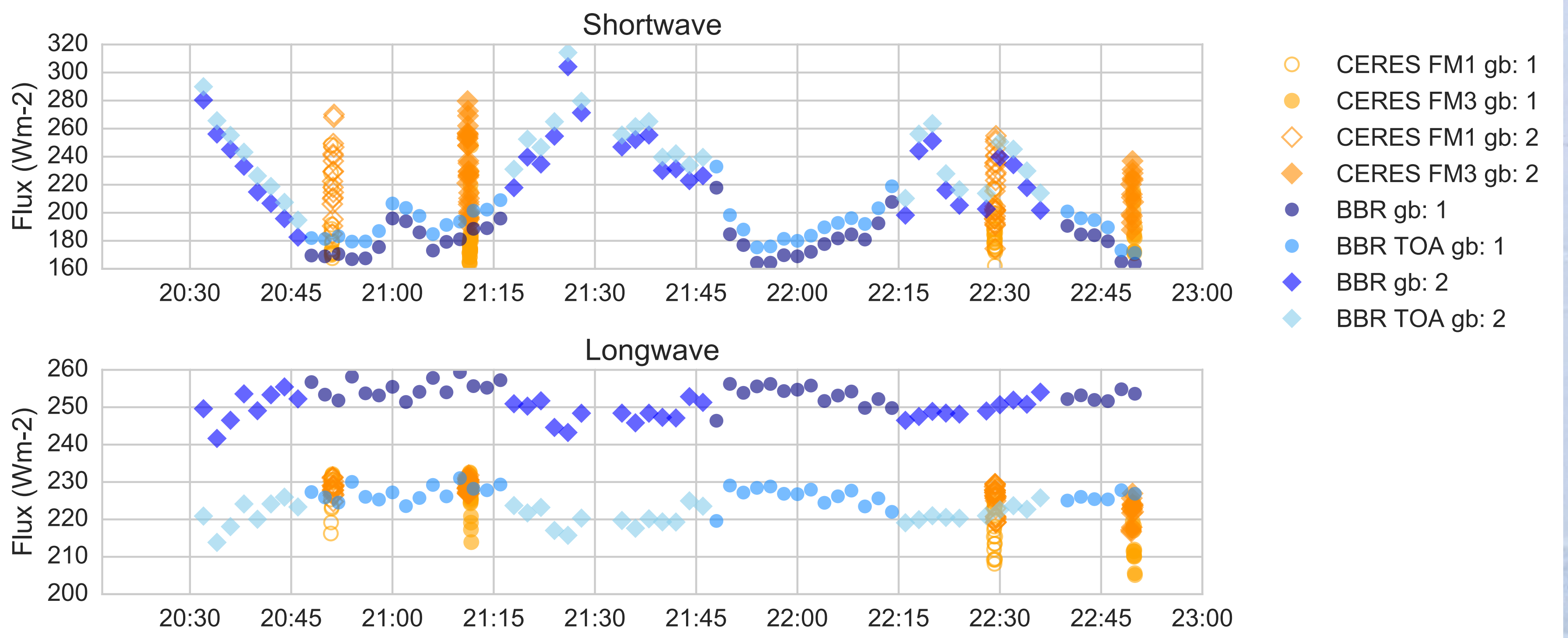
GB07-2:
Marginal Ice Zone, overcast and medium, thick low clouds
- **Cloud fraction:** 99.6%
- **COD:** 9.5
- **CTP:** 899.9 hPa
- **Sea ice:** 13.6 %

CERES SW Flux: 221.4 Wm^{-2}
CERES LW Flux: 226.9 Wm^{-2}
BBR SW Flux: 243.2 Wm^{-2}
BBR LW Flux: 223.2 Wm^{-2}

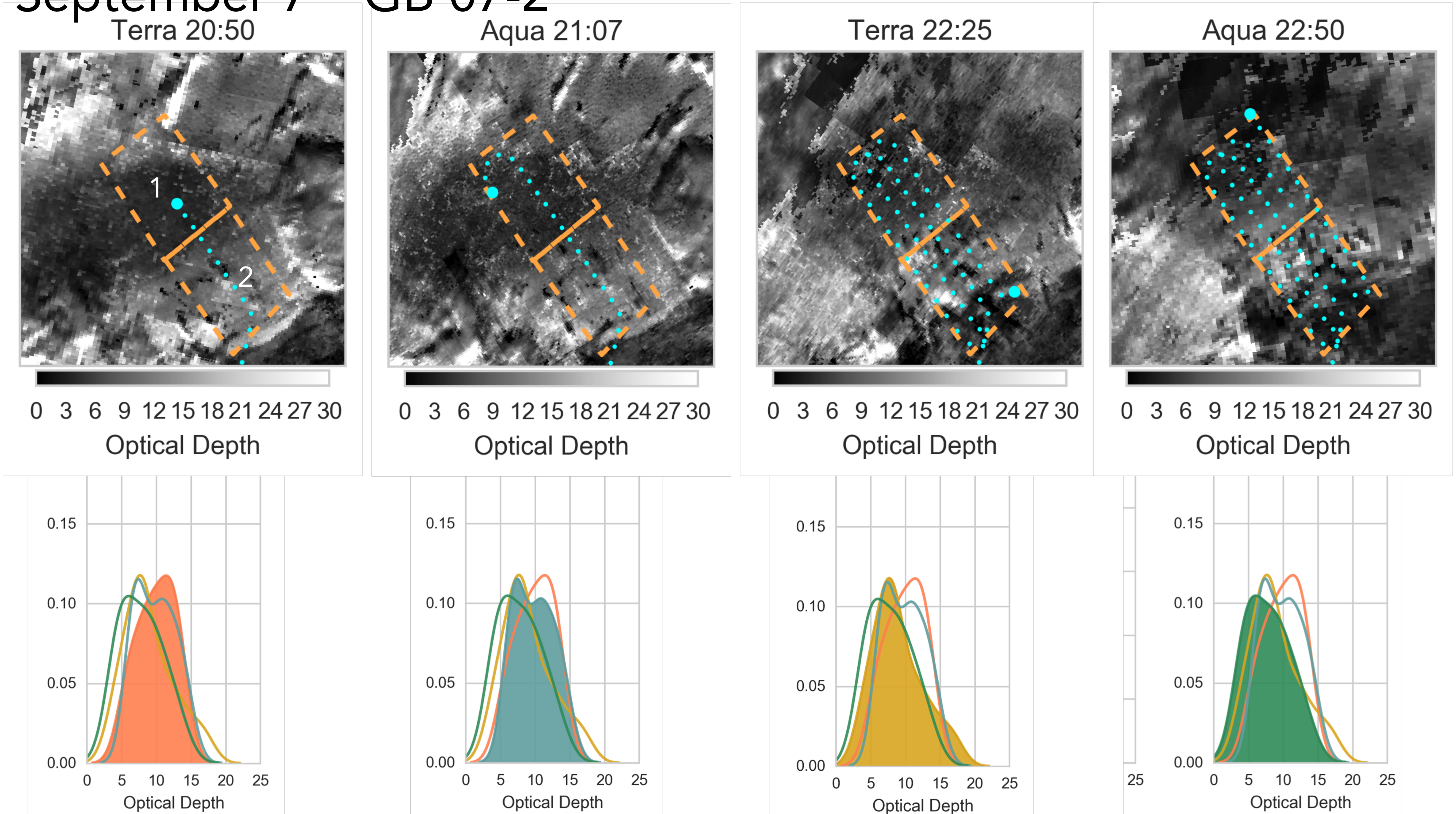
CERES SW:
FM1: 221.2 Wm^{-2} (46)
FM2: 228.8 Wm^{-2} (371)
FM3: 227.0 Wm^{-2} (43)
CERES LW:
FM1: 226.5 Wm^{-2} (46)
FM2: 224.7 Wm^{-2} (371)
FM3: 226.8 Wm^{-2} (43)







September 7th: GB 07-2



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GB0702:
SW Flux:
Aircraft Sampling (closest matching): 255.1 Wm^{-2}
Terra_20 overpass: 258.4 Wm^{-2}
Aqua_21 overpass: 257.0 Wm^{-2}
Terra_22 overpass: 252.3 Wm^{-2}
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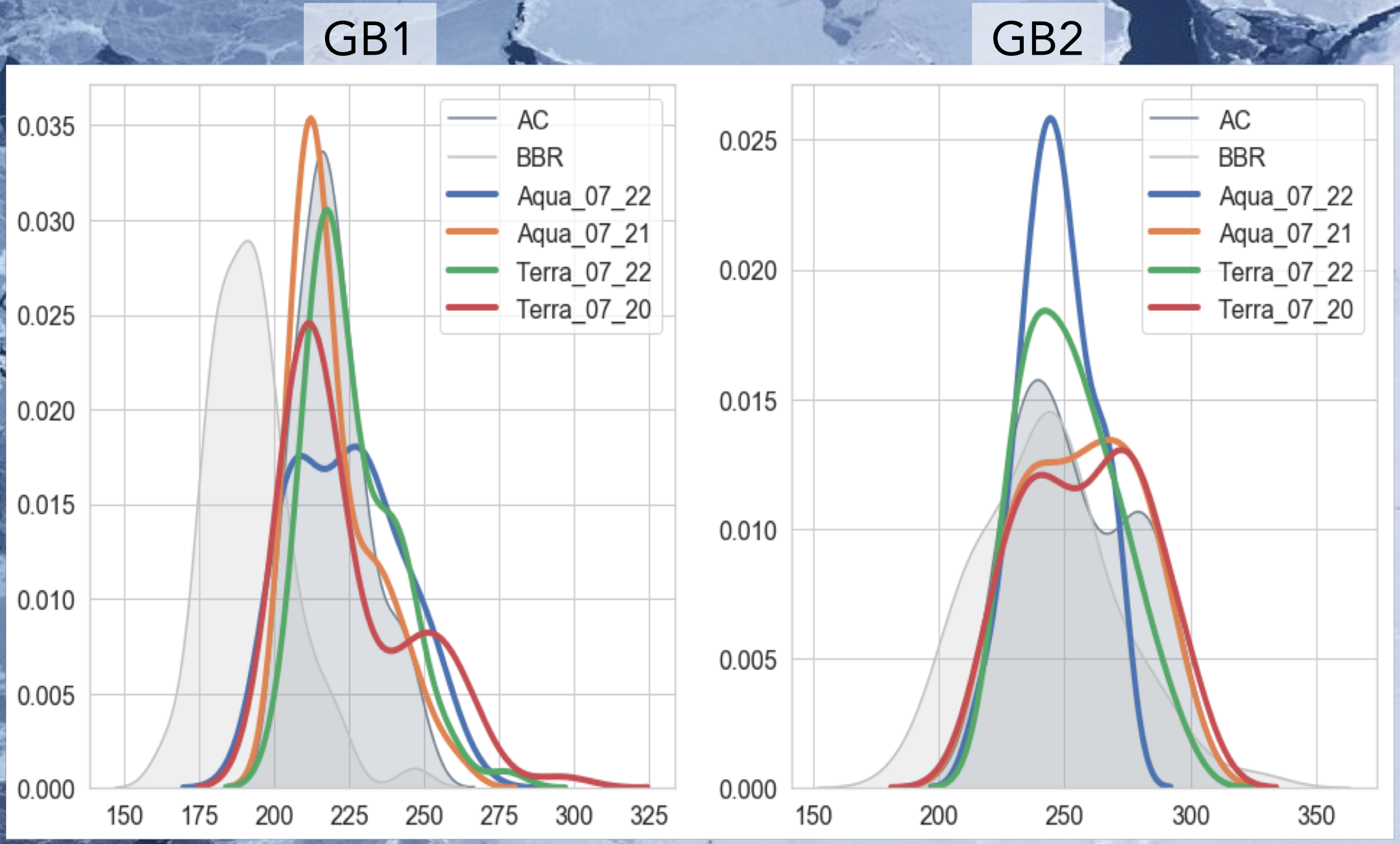
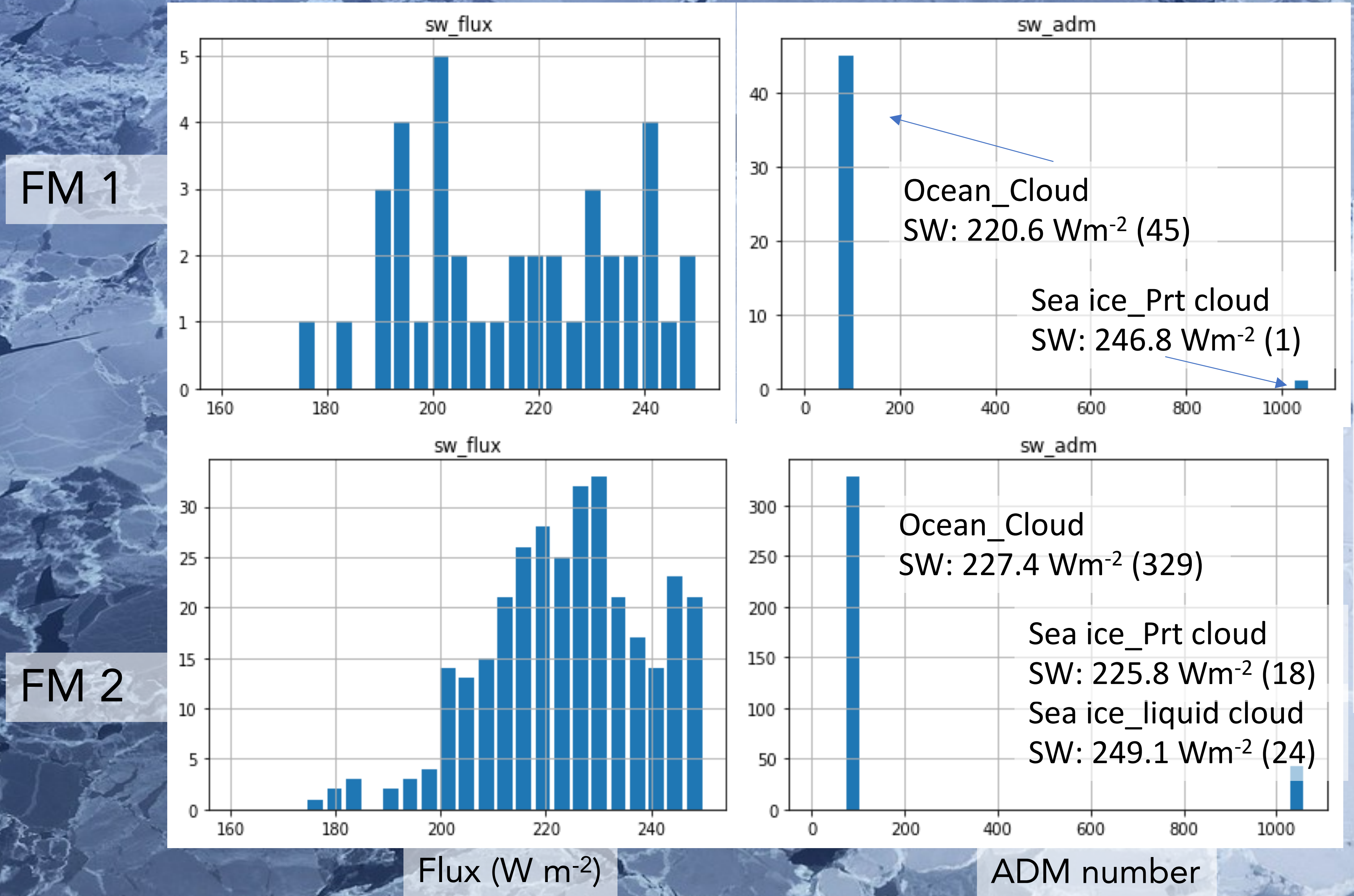
Simulated using MODIS radiances and NB-to-BB, then imposing the aircraft sampling.



Aircraft sampling resulted in a 3.6 Wm^{-2} lower Aircraft flux than if the entire gridbox had been sampled and in GB0702 a 1.4 Wm^{-2} higher flux.

September 7th: GB 07-2, FM1 vs. FM2 comparison



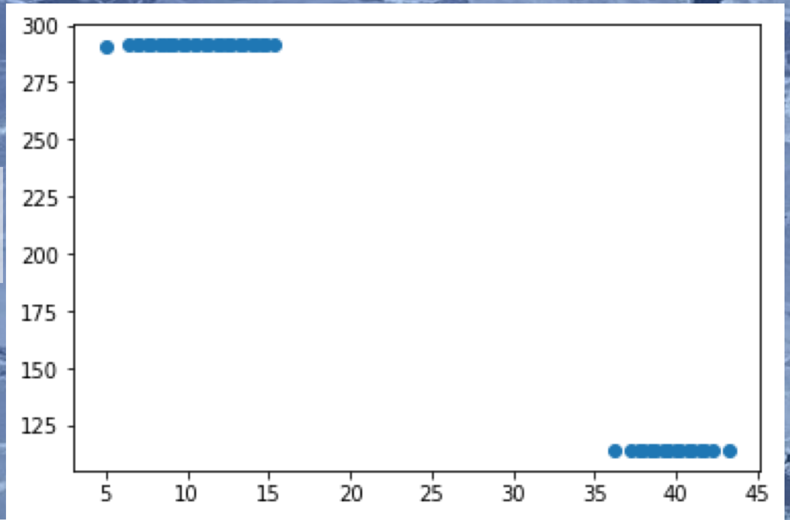
- FM1 only observed 1 sea ice footprint.
- FM2 observed a higher SW flux than FM1 over cloudy sky ocean footprints.

GB07-2: Marginal Ice Zone, overcast and medium thick low clouds, FM1 vs FM2 comparison (geometry)

FM1 CERES SW Flux: 221.2 Wm-2 (46)
FM2 CERES SW Flux: 228.8 Wm-2 (371)
FM1 CERES LW Flux: 226.5 Wm-2
FM2 CERES LW Flux: 224.7 Wm-2

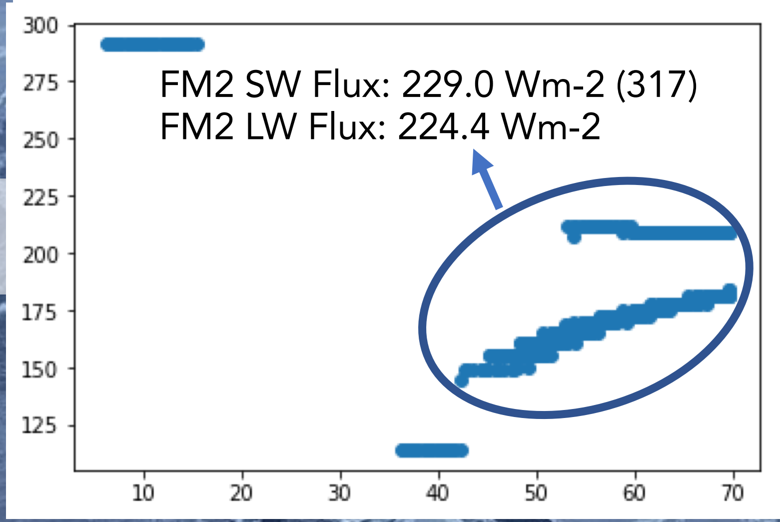
FM 1

RAZ



FM 2

RAZ



VZA

For VZA ,< 15 (all but 3 FOVs cloudy-sky ocean (FM1: 2 and FM2: 1)

- FM1 CERES SW Flux: 218.2 Wm-2 (28)
- FM2 CERES SW Flux: 216.9 Wm-2 (28)
- FM1 CERES LW Flux: 225.1 Wm-2
- FM2 CERES LW Flux: 225.7 Wm-2

For 35< VZA < 45 and RAZ < 125 (all but 1 FOV (FM 2) cloudy sky ocean)

- FM1 CERES SW Flux: 225.9 Wm-2 (18)
- FM2 CERES SW Flux: 231.0 Wm-2 (19), w/ RAZ constraint
- (FM2 CERES SW Flux: 239.0 Wm-2 (26), w/o RAZ constraint)
  - These scenes include more sea ice FOVs
- FM1 CERES LW Flux: 228.5 Wm-2
- FM2 CERES LW Flux: 228.0 Wm-2

Summary

- The gridbox sampling/validation approach proved successful during ARISE (**need more gridboxes**)
  - LW TOA shows good agreement – all differences within the uncertainty.
  - SW TOA not quite as good – 4/5 within the uncertainty.
  - Pervasive negative CERES SW biases relative to Aircraft Observations.

- Instantaneous CERES FOV and Aircraft comparison provide similar results.

- Why the negative SW bias?
  - Sampling differences do not explain it (< 5 Wm^{-2}).
  - Scene ID (Joe didn't think so based upon observer reports)
  - Random Error? (Only have 5 grid boxes)
  - Calibration?
  - ADMs…**we do find that FM2 is brighter for the same ADM scene types at 50-70deg VZAs and 150-225 RAZs.**
- Five data points is not really enough to make strong claims about any biases – more experiments needed!
- Sampling is an important consideration complex scenes (mixtures of ocean and sea ice).
- A potential future approach to get around the sampling issues would be to fly an imager with BBR to concurrently collect flux data with ADM scene ID, such that the simultaneous measurement requirement can be relaxed. (Simulating the CERES process with Aircraft observations)
- MOSAiC opportunity!